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Personal Exposure, Behavior, and Work Site Conditions as Determinants of Blood Lead Among Bridge Painters

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Abstract

Bridge painters are exposed to lead during several job tasks performed during the workday, such as sanding, scraping, and blasting. After the Occupational Safety and Health Administration standard was passed in 1993 to control lead exposures among construction workers including bridge painters, this study was conducted among 84 bridge painters in the New England area to determine the significant predictors of blood lead levels. Lead was measured in personal air and hand wipe samples that were collected during the 2-week study period and in blood samples that were collected at the beginning and at the end of the study period. The personal air and hand wipe data as well as personal behaviors (i.e., smoking, washing, wearing a respirator) and work site conditions were analyzed as potential determinants of blood lead levels using linear mixed effects models. Our results show that the mean air lead levels over the 2-week period were the most predictive exposure measure of blood lead levels. Other individual-level significant predictors of blood lead levels included months worked on bridge painting crews, education, and personal hygiene index. Of the site-level variables investigated, having a containment facility on site was a significant predictor of blood lead levels. Our results also indicate that hand wipe lead levels were significantly associated with higher blood lead levels at the end of the study period compared with the beginning of the study period. Similarly, smoking on site and respirator fit testing were significantly associated with higher blood lead levels at the end of the study period. This study shows that several individual-level and site-level factors are associated with blood lead levels among bridge painters, including lead exposure through inhalation and possible hand-to-mouth contact, personal behaviors such as smoking on site, respirator fit testing, and work site conditions such as the use of better containment facilities. Accordingly, reduction in blood lead levels among bridge painters can be achieved by improving these workplace practices.

Keywords

air lead levels; blood lead levels; bridge painters; hand wipes; lead; work site conditions

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INTRODUCTION

Approximately one million U.S. construction workers are exposed to lead each year, and approximately 50,000 (~5%) of those workers paint and rehabilitate highway and railroad bridges.(1) The Occupational Safety and Health Administration (OSHA) published a final rule for occupational lead exposure in 1978, but the standard did not apply to the construction trades including structural steel painters. Finally, in 1993, OSHA passed a standard for controlling lead exposures in construction that reduced the permissible exposure limit (PEL) from an 8-hr time-weighted average (TWA) of 200 μg/m^3 to 50 μg/m^3 and incorporated additional requirements designed to minimize worker exposures and transport of lead from work sites.

The primary route of occupational exposure to lead is inhalation. Even relatively insoluble forms of lead can be absorbed through the alveoli.(2) Several studies have investigated the relationship between air lead and blood lead levels (BLLs) among workers in different industries. A study conducted among workers in the crystal industry found a statistically significant relationship between personal air lead levels and BLLs.(3) Lai et al.(4) also found that air lead levels, in addition to other determinants such as age, gender, alcohol consumption, and personal hygiene, were significant predictors of BLL among lead battery workers. The association between air lead and BLL may be influenced by a number of factors, including particle size, solubility, lead stores in bone that may be mobilized, and other routes of exposure.(5–7)

Incidental ingestion of lead is another significant potential route of lead exposure that can result from hand-to-mouth activities, such as eating and smoking, and often goes unrecognized in occupational settings.(8–10) Wearing personal protective equipment (PPE) such as gloves has been associated with lower BLL, while the frequency of hand-to-mouth contact on the work site has been associated with increased BLLs among lead-exposed workers even after adjusting for air lead levels.(11) Other studies have investigated the effects of smoking, eating, and personal hygiene on BLL among workers in lead battery plants. For instance, after providing health education to workers of a battery recycling plant in Japan, one study found a mean decrease of 10 μg/dL (from 46 to 36 μg/dL) in BLL over a 3-year period (2000–2003). The greatest decrease in BLL during this period occurred in workers who were nonsmokers and had excellent hygiene (e.g., wearing PPE and washing), although no personal air lead levels were available.(12) Similarly, Chuang et al.(13) found that eating and smoking at the work site regularly (>3 days per week) were significantly associated with higher BLL among lead battery workers who participated in a health promotion program in Taiwan from 1991 to 1997. In addition, workers who smoked and ate at work regularly had a significant increased risk of having an elevated BLL (>40 μg/dL in males and >30 μg/dL in females).(13) Accordingly, personal hygiene and behavioral factors can also influence individuals' personal exposure to lead.

Most previous studies investigating determinants of BLL have relied on exposure measures, such as job titles, ambient air lead levels, or a single personal air lead measurement. While these exposure measures are more readily available, they may introduce exposure misclassification and may not adequately represent the temporal variability in personal exposures. Following the implementation of the OSHA standard for construction workers in 1993, a study was conducted among bridge painters working for eight different contractors in Massachusetts to assess their daily lead exposure during a 2-week period.(14) Bridge painters are exposed to lead through the dust generated during bridge surface preparation tasks, such as abrasive blasting, sanding, grinding, and scraping. Based on their tasks and work site conditions, some workers may be exposed to chronic low levels of lead, and others may be exposed to high levels for short periods. Exposure information collected by task over time for each worker, in conjunction with daily diaries of tasks performed and their duration, can result in less misclassification in estimating daily exposure than is associated with summary exposure metrics, such as job group daily averages that are often used in occupational epidemiology.(15,16) The task-based method of estimating daily exposure is particularly relevant to jobs in the construction industry where tasks and their duration may change from day to day, requiring an approach that accounts for these changes.

Using the exposure assessment data previously described by Virji et al.,(14) the primary objectives of this paper are to: (1) identify the inhalation measure that best predicts absorbed lead measured as BLL at two time points over a 2-week period, (2) evaluate personal air and hand wipe levels as potential determinants of BLL while controlling for potential confounders, and (3) determine whether other individual-level factors (e.g., eating and smoking on site) and site-level factors (e.g., presence of containment facility) also contribute to BLL.

METHODS

Study Population

Eighty-four bridge painters (83 male, 1 female) participated in this study during a2-week work period in 1994 or 1995. The painters worked for eight different contractors on 13 different work sites across New England and performed various job tasks during the study period, including abrasive blasting, scraping, sanding, painting, cleaning, and pressure washing. The number of workers per site ranged from 2 to 12. Each participant provided written informed consent prior to participation in the study. The Human Subjects Committees at Boston University School of Public Health and University of Massachusetts Lowell reviewed and approved all protocols.

Air Monitoring

A total of 268 task-based air samples were collected throughout the study as described previously.(14) Briefly, each participant wore a Gillian GilAir-5 air sampling pump (Sensidyne, Clearwater, Fla.) set at a flow rate of 2.0 L/min attached to an Institute of Occupational Medicine (IOM) sampler with a 25 mm diameter, 0.8 μm pore size, mixed cellulose ester filter to collect the inhalable fraction of lead particulate matter. Samples were collected while performing selected job tasks during at least 1 day over the 2-week study period. The samples were acid digested and analyzed for lead using flame atomic absorption spectroscopy according to NIOSH Method 7082.

Task-specific air lead concentrations were calculated and used to estimate personal daily exposures. The minimum variance unbiased estimator (MVUE) of the task means were used in the time-weighting equations, as this summary measure is the preferred estimator of the true arithmetic mean when the data have a lognormal distribution.(17) In addition, participants completed a diary during each workday of the 2-week period to document the type and duration of each task performed and the type of PPE used. The TWA daily personal lead exposure levels were calculated by combining mean task lead levels with task duration and summing over all the tasks performed in a day and dividing by the total time worked. Daily TWA exposures were estimated for all participants from all the occupations included in the study.

The TWA daily personal lead levels were corrected for respirator use to approximate dose by estimating the lead concentration available for lung deposition. This metric may be more closely associated with BLL. To obtain estimates of task lead exposures corrected for respirator use, the mean task lead levels were divided by the NIOSH assigned protection factor associated with the worker-reported respirator from the daily diary. All air lead measures used throughout this paper were corrected for respirator use.

Additional summary metrics were calculated based on the daily full-shift TWAs described above. For any day that a participant did not work, it was assumed they had zero exposure to lead. Two-week respirator-corrected average concentrations (μg/m^3) were calculated for each participant by taking the arithmetic mean of the daily respirator-corrected air lead levels on all days during the monitoring period. The maximum daily concentration (μg/m^3) was chosen as the day with the highest daily respirator-corrected lead exposure, and the 2-week cumulative exposure (μg/m^3-days) was calculated by summing each daily respirator-corrected concentration.

Hand Wipes

Two hand-wipe samples were collected from individual participants on the day they wore the air sampling pumps. Details of the sample collection and analysis are reported elsewhere.(18) Briefly, each worker was given two Wash 'n Dri towelettes to wipe each hand for 30 sec. Hand wipes were collected during the midshift break and at the end of the work shift after workers had reportedly cleaned up. Although some workers cleaned up before breaks, the midday break hand wipe samples are considered a measure of exposure during the workday (i.e., lead on hands during the work shift), whereas the hand wipe collected at the end of the day is a measure of residual exposure following cleanup activities (i.e., lead on hands as they prepare to leave work). The hand wipe samples were digested using a modified method of Millson et al.(19) and were analyzed by flame atomic absorption spectrometry using NIOSH Method 7082.

Interviews and Observation Logs

Each participant completed a semi-structured interview to obtain information on demographics and behavioral factors, such as respirator use, smoking, and personal hygiene. The interviewer also collected information on potential confounders and other significant predictors of BLL, such as education, training, and hobbies involving lead. All responses were coded and entered into spreadsheets prior to analysis. Additional interviews were conducted with workers to collect qualitative information on individual personal hygiene practices at the end of the work shift on days that they wore the air monitor and/or provided hand wipe samples. A personal hygiene index (PHI) was calculated based on personal responses to six factors. Briefly, workers were asked if they (1) removed their coveralls at break time; (2) washed their hands before their break activity (eating, drinking, and smoking); (3) smoked cigarettes during the work shift; (4) washed their hands at the end of the day; (5) showered at the end of the day, and (6) cleaned their respirator at the end of the day. Each response was assigned a zero (undesirable) or a one (desirable), and the responses were summed and divided by the total number of responses and multiplied by 100 to obtain a percent score for desirable personal hygiene. The PHI scores were then categorized into high (good personal hygiene) and low (poor personal hygiene) by dichotomizing at ≥50%.

Observation logs were also collected by project industrial hygienists on air monitoring days to characterize the work site conditions and health and safety environment. The presence or absence of a respirator program, decontamination and hand washing facilities, types of cleanup practices, and containment structures were noted. Composite scores were also created for these work site variables in a similar manner as mentioned above (Table IV). For example, a composite score was calculated to describe the containment structures on site using a structured form to gather information on 10 variables, including containment facility material, air permeability, support structures, treatment of joints, entryways, air makeup points, input airflow, air pressure and movement inside containment, and exit airflow/dust collection. Each variable was assigned a score from 1 to 10 (10 is best), and a composite score was calculated by summing all variable scores and converting the total into a percent "good" score. The composite score was dichotomized at ≥50% to compare those with good containment facilities to those with poor facilities. Details of other composite scores are given elsewhere.(14,18)

Blood Lead Levels

Blood samples were collected at the beginning of the work shift from each participant on the first day of the monitoring period (Time 1) and again at the beginning of the work shift 2 weeks later (Time 2). Each participant's arm was cleaned with an alcohol wipe prior to blood collection to avoid any external lead contamination of the sample. The blood samples were analyzed for lead at the Massachusetts Division of Occupational Safety Lab (West Newton, Mass.) using graphite furnace atomic absorption spectroscopy method.

Statistical Analysis

All statistical analyses were conducted using SAS version 9.1. Geometric mean concentrations were calculated for air lead levels, hand wipes, and BLL due to the lognormal distribution of the measures.(20) BLLs were modeled (both at Time 1 and Time 2) rather than "change in BLL" because there were four participants who did not have a blood sample drawn at Time 2. Air lead and hand wipe lead levels were also log-transformed because the log transformed exposure variables were better predictors of BLL. This approach is consistent with a recommendation that the log-log model should be used to establish environmental policies for lead in relation to BLL.(21) Mixed models were used to examine the effect of the air lead summary measures and hand wipe levels on BLL to determine which air measure and hand wipe (midshift or post-shift) was the best predictor of BLL. Additional mixed model analyses included other potential predictors of BLL, such as those listed in Appendix 1 (demographics, hobbies, and smoking) and the group-level variables describing the work site and health and safety programs (e.g., presence of a hand-washing facility, cleaning practices, presence of a containment facility). Statistical models were run with and without the addition of hand wipe levels because hand wipes were available only for a subset of participants. Interactions with each of the covariates and time of blood collection (start or end of 2 weeks) were also examined to test whether there was a difference in BLL over time. The significant ($p \leq 0.05$) interactions and main effects were included in the final models. The mixed models accounted for correlation between repeated measurements on the same individual assuming compound symmetry. To account for the potential residual correlation between individuals working at the same site, a random intercept for site was also included.

RESULTS

Study Population

The demographic characteristics of the 84 participants are presented in Table I. The mean age of the participants was 33.2 years (range: 19–55 years), and their mean duration of employment as a bridge painter was 5.9 years (range: <1–33 years). The majority (76%) of the participants were laborers, while 16% were supervisors and 8% were the contractors/business owners who are responsible for setting up the contract with the customers. On average, the participants worked 8 days during the study period (range: 3–11 days). At the time of the study period, 42% of the participants were current smokers, 26% were former smokers, and 31% were never smokers; smoking status was missing for one participant.

Summary of Exposure Data

Table II presents the geometric means (GM) and standard deviations (GSD) for the air lead metrics, hand wipes, and BLLs for all participants. The GMs of the daily average concentrations, the maximum daily average, and cumulative air lead exposures over the 2-week work period were 59μg/m^3, 212μg/m^3, and 767μg/m^3 days respectively for all workers.

There was no statistically significant difference in exposure among the occupational titles, though the sample size was small for supervisors and contractors (data not shown). Of the 84 participants in the study, 58 provided a hand wipe sample of both hands at the time of their midshift break, and 64 participants provided a hand wipe sample at the end of their shift following cleanup (Table II). For those who provided both a midshift and end of day hand sample (n=48), the GM lead levels from the midshift hand wipes were 2.9 times greater than the post-shift hand wipes (925 vs. 321μg lead).

Overall, the GM of BLL was 16.1μg/dL at the beginning of the study period and 18.2μg/dL at the end of the study period. None of the measured BLLs were greater than 50 μg/dL, the OSHA action level leading to the worker's temporary removal from lead exposure. However, 4 of the 84 participants (~5%) had a BLL ≥ 40 μg/dL, which requires that the employer provide blood lead analyses for these workers every 2 months until the levels decrease. Of the remaining participants, 22 (26%) had at least one BLL ≥ 25 μg/dL, 47 (56%) had at least one BLL ≥ 10 μg/dL, and 11 (13%) participants had both BLL < 10 μg/dL.

Air and Hand Wipes Associated with Blood Lead Levels

The daily mean, maximum daily, and cumulative air lead exposures were examined to determine which measure best predicted BLL (Table III). Of the air lead metrics tested, the mean and cumulative measures were statistically significant predictors of BLL and yielded similar results. The interaction between time and the air lead measurements was not statistically significant, indicating that the air lead levels measured during this study had similar effects on BLL collected at the beginning and at the end of the monitoring period. However, there was a significant interaction between the hand wipes collected at midshift and time of BLL collection.

Predictors of Blood Lead Levels

Although occupational title and union membership were not significant predictors of BLL, the laborers had the highest change in BLL compared to supervisors/foremen and contractors (2.1, 0.65, and −0.21 μg/dL respectively) over the two-week monitoring period. While the majority of the study population was white (88%), non-white participants (n=9) had a significantly greater increase in BLL during the study period (4.9 vs. 1.4, p=0.002).

The final models including air, hand wipe lead levels, and the additional significant predictors for BLL are presented in Table V. When considering the model including only air lead levels (no hand wipes), the BLL at Time 2 was significantly higher than at Time 1, and there was a significant main effect for 2-week mean respirator-corrected air lead levels associated with BLL. More specifically, for each additional 10% increase in air lead levels, there was a 1% increase in BLL. A majority of the participants (83%) in this study had been working for at least 1 month since the beginning of the year when they were monitored, indicating that it is possible that the inhalation exposures during this period were not very different from the 2 weeks prior to the study period. Other significant main effects included education, total number of months having worked on bridge painting crews, and personal hygiene. Those who had a high school diploma or less had higher BLL than those with at least some college education, and there was a significant increase in BLL per each month worked as a bridge painter. The personal hygiene index (PHI) was dichotomized into high (good) and low (poor) categories and was negatively associated with BLL such that workers with a low PHI had BLLs that were 31% higher than workers with a high PHI (p=0.02). Of the site-level variables, the containment facility index was positively associated with BLL, indicating that those who worked on sites with good containment facilities actually had BLLs that were 80% higher than those who did not work on sites with good containment structures (p=0.001).

Of the other covariates tested, a significant interaction was found between time and both smoking on site and having respirators fit tested. On average, those who reported that they did smoke on site or did not have their respirator fit tested had greater increases in BLL between Time 1 and Time 2 compared with those who did not smoke on site or had their respirator fit tested.

The second model in Table V includes hand wipe levels in addition to air lead levels. Unlike air lead levels, there was a significant interaction between hand wipe lead levels and time. Hand wipe levels were significantly associated with higher BLL at Time 2 compared with Time 1. While most effect estimates did not change substantially after adjusting for hand wipe lead levels, the beta estimates for the log-log relationship between air lead levels and BLL decreased from 0.11 to 0.05 (i.e., the percent increase in BLL associated with each percent increase in mean air lead levels decreased from 0.1% to 0.05%). This difference must be interpreted with caution because the hand wipe model includes only the subset of the air exposure study participants who also provided hand wipe samples (n= 54). The original air model was run with the same 54 individuals who provided hand wipes (data not shown) and the effect of air lead levels was similar, when not adjusting for hand wipes, ($\beta = 0.06$, SE = 0.07, p-value = 0.33) to that seen in the air and hand wipe model in Table V. This indicates that the change in the effect estimate for air was due to the loss of subjects and not due to the addition of the hand wipes levels. Accordingly, it appears that the subset of individuals who provided a hand wipe sample differs from those who did not provide a hand wipe sample with respect to the effect of air lead levels on BLL. The results from the hand wipe models may not be generalizeable to the remaining participants, but the effect estimates of smoking on site, respirator fit testing, PHI, and containment facility remained similar when including hand wipes.

DISCUSSION

Air lead levels and hand wipe levels were evaluated as potential determinants of BLL, and while mean air lead levels were associated with higher BLL at both times of blood collection (pre and post study period), midshift hand wipe lead levels were significantly associated with higher BLL at the end of the monitoring period compared with BLLs at the beginning of the study period. When comparing the use of the 2-week average air lead levels with other summary measures, very similar results were noted when using the cumulative air lead measure. However, the maximum daily exposure did not predict BLL as well. Although blood is reflective of recent exposure, the half-life of lead in blood is approximately 30 days, so BLLs are a better indicator of chronic exposure to lead rather than very high exposures on a single day.(22)

Particle size may affect the time course for absorption of lead. Specifically, only the respirable fraction (≤10 μm) is generally deposited in the alveolar region of the lung.(23) The absorption of the respirable fraction into the blood is more immediate due to the smaller particle size and explains greater variability in BLL.(5) In fact, some have shown that the relationship between air lead levels and BLL is substantially decreased after adjusting for the respirable fraction of particulate matter.(24) Since the exposure metrics in the present study are based on the inhalable fraction of particulate matter (<100 μm), a large fraction of the lead content was in the nonrespirable particle size range and possibly contributed to some exposure misclassification that resulted in less significant air-blood lead relationships. Limited data on the respirable fraction in our study varied by job task ranging from 11.8% for taking down tarps to 36.3% for job activities taking place <6 meters from a containment structure.(14)

In addition to personal air and hand wipe lead exposure, this study evaluated demographics, work site characteristics, and personal behaviors that may contribute to higher BLL among workers. After adjusting for the air and hand wipe lead levels, education level, smoking on site, and respirator fit testing were significant predictors of BLL. While controlling for air lead levels that were respirator adjusted for the time that a respirator was worn, fit testing appears to be an important determinant of BLLs suggesting that fit testing is essential to fully benefit from respirator use. In addition, behaviors involving hand-to-mouth contact such as smoking may lead to additional exposure via ingestion. Similarly, our results suggest that personal hygiene practices such as washing before eating and smoking, changing clothes, showering, and cleaning respirators should be implemented to minimize additional exposure to lead. The ability of a worker to perform these individual practices is dependent on work site facilities and conditions. Although not statistically significant in the final models, those who worked on sites with good hand washing facilities and cleaning practices had smaller changes in BLL compared with those with poor hand washing facilities and cleaning routines (data not shown).

A higher score for the containment structure was significantly associated with higher BLL. Containment structures are designed to prevent fugitive emissions from entering the environment by containing lead exposures generated during job tasks, such as abrasive blasting or scraping within the enclosure. Although containment may reduce the environmental impact of lead exposures, such facilities may actually lead to higher personal exposures to the workers inside the containment when engineering controls such as general exhaust ventilation are not incorporated into the containment. Though few individuals spend their work shift working inside the containment area, increased BLLs among other workers may have resulted from setting up and taking down tarps for containment, and cleaning tasks associated with containment. Although not exposed to lead dusts during activities inside containment, workers may have been exposed while performing these other tasks associated with maintenance of the containment facility.

Prior to 1993, the construction trades were not protected under OSHA’s lead standard for general industry.(25) Documented cases of acute lead poisonings among ironworkers who were disassembling and deconstructing a bridge in New York in 1987 demonstrated a need for the inclusion of a lead standard for workers in the construction industry.(26) The overall aim of this study was to evaluate the effectiveness of the 1993 OSHA Lead in Construction Standard in reducing personal exposures to lead among bridge painters. Lower BLLs were observed among ironworkers within the first year of the implementation of the OSHA Lead in Construction Standard in 1993, although it is unclear which of the mandated controls were most effective in lowering BLLs.(26) Unlike the study conducted by Levin et al.,(27) it was not possible for us to compare BLLs among workers prior to and after the implementation of the OSHA Lead in Construction Standard; instead, the differences in BLLs were investigated among bridge painters on work sites with different degrees of compliance with the OSHA standard. Although none of the participants in this study had a BLL greater than 50 μg/dL, requiring removal from lead exposure, roughly 5% had a BLL greater than 40 μg/dL, which requires blood monitoring every 2 months. In addition, work site facilities were not always updated according to the new OSHA standard. For example, 8% of the participants (from three different work sites) reported having no drinking water available, 7% (from two work sites) reported not having water for washing, 12% (from two work sites) reported having no showers available. In addition, 45% of the participants reported that they did not have a designated eating area. Our findings regarding the impact of hand wipe samples on BLLs suggest that the implementation of these work site facilities as required by OSHA could lead to additional reductions in workers’ BLLs.

CONCLUSIONS

Personal exposure to airborne lead, hand wipe lead levels, personal behaviors, and work site conditions were evaluated as potential predictors of BLL among bridge painters after the implementation of the 1993 OSHA Lead in Construction Standard. There was a significant positive association between mean respirator-adjusted air lead levels and BLL. In addition, hand wipe lead levels were associated with higher BLL at the end of the 2-week study period compared with the beginning of the study period. Other significant predictors of BLL among these bridge painters included smoking on site, respirator fit testing, personal hygiene practices, and the use of containment facilities on site. While it was not possible to compare the BLL with those prior to the 1993 OSHA standard, the findings indicate that greater compliance with the OSHA standard results in lower BLLs among bridge painters.

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TABLE I

Demographics for Bridge Painters

Participant Characteristics	N=84
Mean age (range)	33.2 (19–55)
Mean years worked on bridge painting crews (range)	5.9 (<1–33)
Since January, how long have you done bridge work? n (%)	
< 1 month	14 (17)
1–3 months	42 (50)
>3 months	28 (33)
Occupational title, n (%)	
Worker/laborer	64 (76)
Supervisor/foreman	13 (16)
Contractor	7 (8)
Union member, n (%)	
No	66 (79)
Yes	18 (21)
Education, n (%)	
≤ High school	62 (75)
> High school	21 (25)
Race, n (%)	
White	74 (88)
Nonwhite	9 (11)
Missing	1 (1)
Marital status, n (%)	
Married	43 (51)
Single	32 (38)
Separated/Divorced	9 (11)

TABLE II

Summary Measures for Lead

Sample	n	GM (GSD)	Min	Max
Air (respirator-corrected)				
2-week average (μg/m^3)	84	58.8 (2.8)	1.2	396
Maximum daily (μg/m^3)	84	211.9 (3.2)	4.0	4247
Cumulative (μg/m^3-days)	84	767.2 (2.7)	16.2	5542
Hand wipes				
Midshift (μg lead)	58	793.1 (3.7)	31.9	32351
Post-shift (μg lead)	64	388.8 (4.4)	8.5	8370
Blood				
First day (μg/dL)	84	16.1 (1.7)	3.0	49.5
Last day (μg/dL)	80	18.2 (1.6)	3.0	42.0

TABLE III

Air Lead and Hand Wipes Associated with Blood Lead in Univariate Analyses

Sample	BLL β(SE)	BLL p-value
Air (respirator-corrected)		
2-week average (μg/m^3)	0.10 (0.05)	0.05
Maximum daily (μg/m^3)	0.07 (0.05)	0.16
Cumulative (μg/m^3-days)	0.10 (0.05)	0.05
Hand wipes		
Midshift (μg lead)	0.16 (0.06)	0.007
Post-shift (μg lead)	0.06 (0.05)	0.24

Note: Air lead, hand wipe, and blood lead levels are natural log transformed.

TABLE IV

Summary Indices as Percent "Good" Characteristic

Index	n	Median	Min	Max
Individual-level				
Personal hygiene index	66	33	0	100
Site-level indices				
Respirator program	13	75	0	100
Decontamination facility	13	86	29	100
Hand wash facility	13	20	0	80
Cleanliness factors	13	42	18	67
Containment facility	13	53	47	75

Note: A similar table has been published by Virji et al.(17)

TABLE V

Final Models Evaluating Significant Predictors of BLL

Parameters	BLL (Air Only) β(SE)	p-value	BLL (Air and Hand Wipe) β(SE)	p-value
Intercept	1.90 (0.24)	<0.0001	2.12 (0.44)	0.0007
Time of BLL (end vs. start of study)	0.16 (0.04)	<0.0001	−0.31 (0.11)	0.005
Mean air lead (μg/m^3)	0.11 (0.05)	0.03	0.05 (0.07)	0.45
Hand wipe at break (μg lead)	—		0.007 (0.06)	0.91
Hand wipe at break * time	—		0.07 (0.01)	<0.0001
Months on bridge painting crews	0.001 (0.0004)	0.03	0.001 (0.0006)	0.04
Education				
≤ High school	0.38 (0.10)	0.0002	0.29 (0.13)	0.03
> High school	Ref.		Ref.	
Respirator fit test				
No	−0.14 (0.14)	0.32	−0.13 (0.21)	0.53
Yes	Ref.		Ref.	
Respirator fit test * time of BLL				
No	0.18 (0.06)	0.003	0.17 (0.07)	0.01
Yes	Ref.		Ref.	
Smoke on site				
No	0.14 (0.09)	0.14	0.15 (0.10)	0.14
Yes	Ref.		Ref.	
Smoke on site * time of BLL				
No	−0.15 (0.05)	0.002	−0.11 (0.04)	0.009
Yes	Ref.		Ref.	
Personal hygiene index				
Low	0.27 (0.11)	0.02	0.29 (0.12)	0.02
High	Ref.		Ref.	
Site-level variables				
Containment facility				
Poor	−0.59 (0.18)	0.001	−0.57 (0.22)	0.01
Good	Ref.		Ref.	

Note: Air lead, hand wipe, and blood lead levels are natural log transformed.